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Design of an Automated System for a Drinking Water Treatment Plant

Diseño de un Sistema Automatizado para Planta de Tratamiento de Agua Potable

David Camilo Rodriguez-Silva*[1]*, Jose Luis Vargas-Figueredo*[2]*,

***Javier Eduardo Martinez-Baquero*[3]**

Abstract

The Municipality of Restrepo, Meta (Colombia), supplies water from the Caney River to the population through the Emiliano Restrepo Echeverría water treatment plant, with a capacity of 84.5 L/s. However, the lack of an efficient control system has been a challenge. To address this deficiency, an automatic dosing system for reagents such as 10% aluminum sulfate, caustic soda, sodium hypochlorite, and calcium was designed, using sensor data from devices like flow meters, pH meters, and turbidity meters. The design, based on the grafcet method and programmed in TIA Portal V16, includes a Human-Machine Interface (HMI) that displays the system's behavior and potential errors. Additionally, a feature has been incorporated to allow automatic transition to manual mode in case of technical failures or when operator intervention is necessary. This system not only records physicochemical

[1] Ingeniero Electrónico. Universidad de los Llanos. Colombia. E-mail: david.rodriguez@unillanos.edu.co ORCID: https://orcid.org/0009-0008-2774-548X7

[2] Ingeniero Electrónico. Universidad de los Llanos. Colombia. E-mail: jose.vargas@unillanos.edu.co ORCID: https://orcid.org/0009-0004-3736-0453

[3] Especialista en Instrumentación y Control Industrial. Universidad de los Llanos. Colombia. Docente de Planta Universidad de los Llanos. E-mail: jmartinez@unillanos.edu.co ORCID: https://orcid.org/0000-0003-4377-7867

variables but also controls dosing through electromechanical pumps to ensure the quality of water supplied to the population of Restrepo.

Keywords: Automation, drinking water, dosing, monitoring, water plant treatment.

Resumen

El Municipio de Restrepo, Meta (Colombia), abastece agua del Río Caney a la población mediante la planta de tratamiento Emiliano Restrepo Echeverría, con una capacidad de 84.5 L/s. Sin embargo, la falta de un sistema de control eficiente ha sido un desafío. Para abordar esta carencia, se diseñó un sistema automático de dosificación de reactivos como sulfato de aluminio al 10%, soda cáustica, hipoclorito de sodio y calcio, empleando datos de sensores como caudalímetro, pHmetro y turbidímetro. El diseño, basado en el método grafcet y programado en TIA Portal V16, incluye una Interfaz Hombre-Máquina (HMI) que muestra el comportamiento del sistema y posibles errores. Además, se ha incorporado una función que permite la transición automática a modo manual en caso de fallas técnicas o intervención necesaria del operario. Este sistema no solo registra las variables fisicoquímicas, sino que también controla la dosificación mediante electrobombas para asegurar la calidad del agua suministrada a la población de Restrepo.

Palabras clave: Agua potable, automatización, dosificación, monitoreo, planta de tratamiento.

1. Introduction

The Colombian territory has a diversity of aquatic ecosystems, which makes it one of the countries with the greatest amount of fresh water in the world[1], his allows a wide distribution to the population and industries, which is why it is essential to have a Drinking Water Treatment Plant (DWTP) to purify the water of its sediments and make it suitable for human consumption. The automation of industrial processes[2][3] in Colombia has been growing over the years[4] and the pandemic teaches us that for the survival of a company it is essential and not an option to have these technological transformations in its production [5][6][7]. The magazine portfolio in one of its publications in 2021 emphasizes that "to advance rapidly in the economic reactivation depends on the level of automation in the productive sector". This indicates that the benefit increases directly proportional to the level of autonomy in the processes[8]. Automation has a wide range of applications in the industry. [9][10] to improve the efficiency and effectiveness of companies that want to improve [11], in addition to the high level of security that this offers when controlling variables in production processes[12][13]. The industrialization of industrial processes is a growing trend in Colombia that offers a number of benefits, such as improved efficiency, effectiveness and safety[14].

Making water drinkable[15][16] and sanitation[17][18] is vital to human health [19][20][21][22] and even more so that the World Health Organization for the Covid-19 pandemic emphasized access to clean water and hygiene to contain and prevent the spread of diseases, such as pathogens and infections, including Covid-19 with good hand washing. The UN Sustainable Development Goal 6 is to ensure the availability of water and its sustainable management and sanitation for all, demanding much control and supervision in each of the processes of water treatment to make it fit for consumption; for this reason it is necessary the use of automation to ensure the safety and efficiency of these processes [23].

The automation development model [24] of this project is applicable to any industry dedicated to the consumption of large quantities of water, providing economic benefits for the plants, avoiding stopping processes due to human error as it is monitored by the automation[25], generating alarms when a malfunction is detected; reducing time to be effective at the time of acting and making the distribution of the resource efficient; ensuring health for consumers; as well as reducing physical risks for operators by letting the technology handle chemicals, or making bad forces when opening floodgates of tributary channels[26].

2. Materials y methods

To carry out the development of this project, a methodology is divided into 4 phases, which are carried out according to the established times in order to follow up and qualitatively evaluate the fulfillment of the activities proposed in each one of them. The description of each of the phases is presented below.

Phase 1: Compilation of information related to the processes carried out at the Drinking Water Treatment Plant.

Phase 2: Conduct a visit and a compilation of information on the current state of the operation and infrastructure of the Drinking Water Treatment Plant.

Phase 3. - Analyze the information collected.

Phase 4: Identify improvement alternatives for the Drinking Water Treatment Plant.

The measurement points were analyzed with reference to the current RAS standard. This highlighted the fundamental aspects for automation and provided essential information for the evaluation of the complexity of the systems, taking into account both their structure and their current processes. Such classification plays a key role in the design process.

The information in the classification includes a table detailing the measurement points in relation to processing, monitoring, control, logging and external computer interactions.

After a thorough analysis of the processes and structures within the DWTP, as well as a projection into the future, it was concluded that the system has a medium-high complexity. This constitutes the essential basis of the system. Table 1 compiles the measurement points and ranges that are indispensable in the automation system.

Table 1. Compilation of measurement points and ranges that are indispensable in automation systems.

NORMAS	OBLIGATORIO				OPCIONAL			
PROCESO	**INSTRUMENTACIÓN**	**MEDICIÓN**	**CONTROL**	**REGISTRO**	**INSTRUMENTACIÓN**	**MEDICIÓN**	**CONTROL**	**REGISTRO**
PRETRATAMIENTO								
General	Caudal afluente	Automático		Continuo				
					pH agua cruda	Automático		Continuo
					Turbiedad	Automático		Continuo
Dosificación de alcalinizante					pH ajustado (después de alcalinización)	Automático	Automático	Continuo
Aeración	Oxígeno disuelto agua cruda	Manual	Manual	Planilla de datos	Oxígeno disuelto agua cruda	Automático	Automático	Continuo
	Oxígeno disuelto agua aireada	Manual	Manual	Planilla de datos	Oxígeno disuelto agua aireada	Automático	Automático	Continuo
COAGULACIÓN								
General	pH agua coagulada	Manual		Planilla de datos	pH agua coagulada	Automático		Continuo
					Monitor de SCM	Automático		Continuo
	Temperatura	Manual		Planilla de datos	Contador de partículas	Automático	Automático	Continuo
	Aluminio residual (en efluente de la planta)	Manual		Planilla de datos	Aluminio residual (en efluente de la planta)	Automático		Continuo
Control del nivel del agua	Nivel del agua	Manual	Manual	Planilla de datos	Nivel del agua	Automático	Automático	Continuo
					Control de dosificación por regulación del SCM u otro desarrollo tecnológico.		Automático	Continuo
Dosificación de coagulantes	Según estrategia de control (Control de caudal o control de pH de coagulación. Ver tabla C.15.2)		Automático	Continuo				
FLOCULACIÓN								
General	Nivel del agua	Manual	Manual	Planilla de datos	Nivel del agua	Automático	Automático	Continuo
					Contador de partículas	Automático	Automático	Continuo
Control de dosificación de otros productos (si los hay)	Según diseño	Manual	Manual	Planilla de datos	Según diseño		Automático	Continuo
Control de Floculadores Mecánicos					Según diseño		Automático	Continuo
SEDIMENTACIÓN								
General	Turbiedad del efluente	Manual	Manual	Planilla de datos	Turbiedad del efluente	Automático	Automático	Continuo
	Color verdadero	Manual						
	Nivel del agua	Manual	Manual	Planilla de datos	Nivel del agua	Automático	Automático	Continuo
Sistema de extracción de lodos	Nivel de los lodos	Manual	Manual	Planilla de datos	Nivel de los lodos	Automático	Automático	Continuo
FILTRACIÓN								
General	Caudal por filtro	Automático		Continuo				
	Presión (Pérdida de carga)	Automático		Continuo				
	Turbiedad del efluente por filtro	Manual		Planilla de datos	Turbiedad del efluente por filtro	Automático		Continuo
	Color	Manual		Planilla de datos				
	Nivel del agua	Manual	Manual	Planilla de datos	Nivel del agua	Automático	Automático	Continuo
Sistema de lavado	Según diseño		Automático	Continuo				
DESINFECCIÓN								
General	pH	Manual		Planilla de datos	pH	Automático		Continuo
	Residual del desinfectante	Automático		Continuo				
Dosificación del desinfectante	Según estrategia de control (Control de dosis constante o control del residual del desinfectante. Ver tabla C.15.1)		Automático	Continuo				
ESTABILIZACIÓN								
General	pH	Manual		Manual	pH	Automático		Continuo
Dosificación	Según estrategia de control (Control de dosis constante o control de pH para estabilización)		Manual	Planilla de datos	Según estrategia de control (Control de dosis constante o control de pH para estabilización)		Automático	Continuo
OTROS								
Tanques	Caudal efluente (tanque de almacenamiento)	Automático		Continuo				
	Nivel del agua	Manual	Manual	Planilla de datos	Nivel del agua	Automático	Automático	Continuo
Bombeos	Velocidad del motor	Automático	Automático	Continuo				
	Temperatura del motor	Manual	Manual	Planilla de datos				
Manejo de lodos	Nivel de los lodos	Manual	Manual	Planilla de datos	Nivel de los lodos	Automático	Automático	Continuo
	Concentración de lodos	Manual	Manual	Planilla de datos				

Source: own.

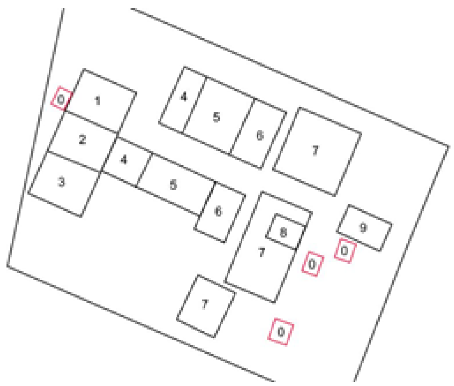
2.1. Description of the DWTP

The plant has the distribution shown in Figure 1, a total of 9 zones can be observed, and a zone 0 where the flow sensors are located. These zones are:

0. Caudalímetros.
1. Office and Laboratory.
2. Dosing and Rapid Mixing.
3. Warehouse.
4. Flocculation.
5. Sedimentation.

6. Disinfection.
7. Water storage tanks.
8. Chlorine storage.
9. Sludge well.

Figure 1. Distribution of the DWTP



Source: own.

The water collected from the Caney River enters the plant directly to the dosing and rapid mixing zone, passing through a flow meter beforehand. In this sector, Caustic Soda Flakes, Sodium Hypochlorite 15% min. and Solid Aluminum Sulfate Type A are applied; the amount of coagulant and pH corrector is determined depending on the measurements taken by the operators. See figure 2.

Figure 2. *a) Rapid mixing (Parshall flume) b) Tanks with Coagulant and pH Corrector*

Source: own.

In the Parshall flume (Figure 2a) a turbulence is created that is suitable for rapid mixing, and the supply is controlled by means of the tank valves (Figure 2b). The water is then directed to the flocculation tanks (Figure 3), where it passes through separate tanks to create coagulates. The DWTP has two parallel process lines for water treatment, in case drinking water consumption increases and the potabilization process is affected.

Figure 3. Flocculation Tanks

Source: own.

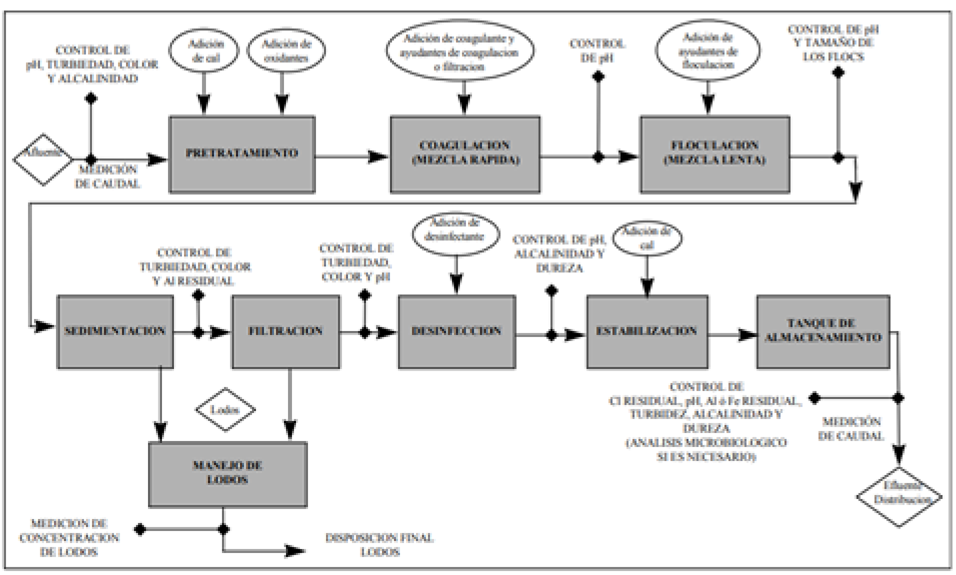
The quality parameters of treated water to be supplied to the population must be in accordance with the limits defined in Decree 1575 of 2007 and Resolution 2115 of 2007.[27], by which the technical standards for drinking water quality are issued by the Ministries of Environment, Housing and Territorial Development and Social Protection. Consequently, the following ranges were determined for the physical-chemical parameters for samples taken at the inlet and outlet of the DWTP: turbidity, color, pH and free residual chlorine, as shown in Table 2.

Table 2. Characteristics of water for human consumption relevant to the Emiliano Restrepo Echavarría DWTP

Parameter	Normative Range (Res. 2115 de 2007)	Unit
Turbidity	<2	NTU
Apparent Color	<15	UPC
pH	6.5 – 9.0	Units
Temperature	Not specified	°C
Chlorine Residual	0.3 – 2.0	(mg Cl_2)/L
Smell and taste	Acceptable	N/A
Dissolved oxygen	> 1.0	mg/L

With these ranges it is possible to assign the optimal operating limits and certain eventualities that may occur in the automated system. For the measurement points, the diagram provided by the RAS was used as a reference [28] (figure 4), which is a basis for the automation system. In this diagram the process functions, monitoring, control, records and external changes with computers are indicated.

Figure 4. Example of process and instrumentation diagram for conventional processing



Source: own.

Based on the above, there is a representation and the reference points of each action, in addition to the current diagram of the DWTP processes (Figure 5) and taking into account its infrastructure, a projection of the places where the installation of the sensors is optimal can be made (Figure 6).

Figure 5. Emiliano Restrepo Echavarría DWTP process diagram

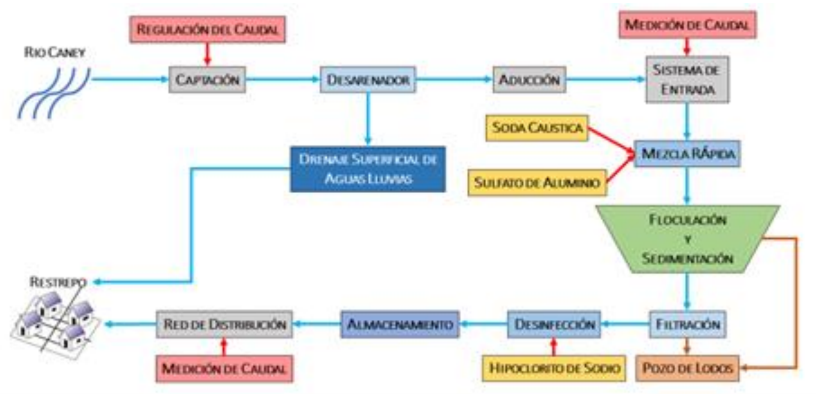


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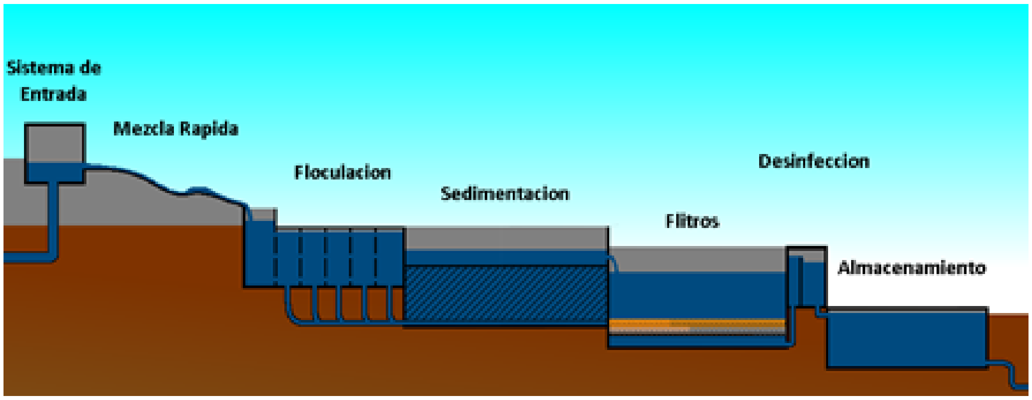
Figure 6. Projection of sampling points.



Source: own.

To date, there are 2 modules for the flocculation, sedimentation, filtering and disinfection stages in the DWTP. Therefore, at some sampling points 2 sensors are required for the same stage.

2.2. Sensor selection

The number of sensors required is compiled in Table 3, in its implementation the system is classified in the medium-high level of complexity.

Table 3. Measurement points and variables

Measuring point	Variables measured	Number of sensors
Entry system	Inlet flow rate *	1
	pH in raw water	1
	Turbidity	1
Dosage	Chemical level	2
Filters	Flow rate per filter	2
Disinfection	Chemical level	2
Storage	Free chlorine	1
	pH	1
	Turbidity	1
	Level	3
Distribution Network	Outlet flow rate *	5

Source: own.

* ***Some flow sensors are already installed and only modifications to the connections are required to obtain the measurements.***

Table 4 shows the selected sensors and their prices.

Table 4. Devices selected for the automation system

Parameter	Sensor*	Measuring range	Precision	Resistant to	Exit Signal	Individual Price (USD)	Number of sensors	Total Price (USD)
PH	**PC1R1N**	0 – 14 pH	± 0.1 pH	Water and dirty media	4 – 20 mA	387.52	2	775.04
Turbidity	**ST-730 B**	0 a 1000 NTU	± 2% FS	Water and dust	4 – 20 mA	1,469	2	2938
Level	**RKL-01**	0 a 200 m	0.1% FS	Water and dust	4 – 20 mA	169	7	1183
Free Chlorine	**FCLTX-110**	0 a 10 ppm		Water and dust	4 – 20 mA	1267	1	1267
Flow	**SITRANS FM MAG 8000 / MAG 8000 CT****	Max. 40 bar	0.2% ± 2mm/s	Water and dust	4 – 20 mA	1088.5	2	2177
Total Sensors							14	—
Total Cost							—	8340.04

Source: own.

The dosing process is paramount to bring the raw water to acceptable drinking water ranges. For this purpose, coagulants, polymers and pH correctors are used. In the case of pH and turbidity, stabilization is done by dosing Aluminum Sulfate type A (flakes) and Sodium

Hydroxide (granules), which are dissolved in water in their respective storage tanks. The dosage is liquid and the dose is obtained based on the laboratory analysis that provides the initial values. In the case of disinfection, when performed by liquid chlorine, it is possible to determine the dosage to be applied according to the flow rate, chlorine demand, free chlorine and percentage of chlorine in the disinfectant used. According to the chlorination manual [29], the chlorine dose to disinfect the water is equivalent to the equation (1):

$$\textbf{Chlorine dosage (mg/L) = Chlorine demand (mg/L) + Free residual chlorine (mg/L)} \quad (1)$$

In Colombia, the standard establishes that drinking water must contain at least 0.3 mg/L of free residual chlorine. Therefore, the chlorine dosage will be as indicated in the equation (2):

$$\textbf{Chlorine dosage (mg/L) = Chlorine demand (mg/L) + 0.3 mg/L} \quad (2)$$

As can be seen, it is very important to determine the chlorine demand in order to establish the dose of chlorine to be applied in the chlorination of the water. The chlorine demand is determined by the break point found in the water.

Below, in Table 5, are the options for liquid dosing:

Table 5. Liquid Dosing Options.

Characteristics	**1. Tekna APG 800**	**2. PULSAtron Series E Plus LPH8**	**3. LMI C741-36**
Reference image			
Control	4 a 20 mA	4 a 20 mA	4 a 20 mA
Voltage	100 – 240 V	115 – 230 V	115 V
Operating Range	1090 L/h	94.6 L/h	76 L/h
Price	425 USD	1908 USD	2567

The dosing unit* selected is the Tekna APG 800, and 4 units are required for a total price of 1700 USD.

2.3. System requirements

One of the fundamental steps in the development of the automation system is the operation specifications in the inputs and outputs (I/O) that are present in the current processes of the DWTP.

These specifications guarantee the quality of the water and that the automated system can be realized on the basis of a Programmable Logic Controller (PLC), the latter being the most relevant to determine the realization software, I/O modules, communication modules, extra hardware and the visualization of the DWTP status.

The general requirements and that complies with the conditions of the company AGUAVIVA S.A.S.[30] The following are related to the functionality of the automation system:

- Observation screens will show the readings and status of the variables that are constantly measured.
- The observation screens will persistently indicate the status of the valves, activation and alarms.
- The supervision system offers three operation options, so that the automation system does not limit and allows manual operation of the plant.
- In the operation sequence it will be possible to choose which type of operation to use.
- The system status is intended to be didactic and easy to read.
- It is intended that all measurements of the water quality variables are displayed on the screens available.
- Create a system that allows to observe the emergency situation of the DWTP.
- Alarm conditions need an efficient warning system.

- The inflow and outflow, together with the parameters of the raw water and treated water are stored in a database.

2.4. Operation sequences

The programming of the operation modes is defined according to the following sequences that can be performed by the DWTP:

- Automatic operation sequence
- Maintenance sequence.
- Manual operation sequence.

These operating sequences are taken from the operating manual in conjunction with the procedure performed by the operators on a day-to-day basis.

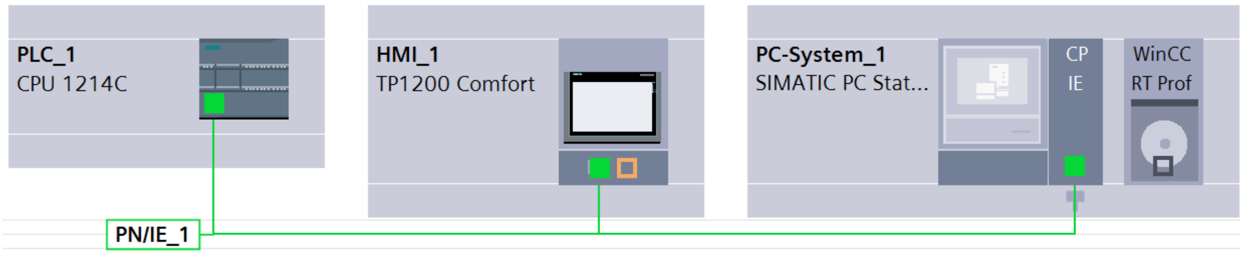
2.5. Automated system design

Continuing with the development of the project and based on the requirements and characteristics that were determined in the planning stage, the details of the operation modes, graphic interface and configuration of the PLC and the modules within the TIA Portal Software must be defined.

2.5.1. Configurations of the PLC y modules

Figure 7 below shows the devices that will be connected through the same network, for which IP's must be assigned to the designated subnet. In addition to the Ethernet connection, an HDMI connection must be made between the PLC and the TP1200 screen, and between the PLC and the PC.

Figure 7. Devices and Networks



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2.5.2. Assignment of variables in the PLC

Next is the creation of the I/O table in the TIA PORTAL software with which one of the bases for programming the operating modes can be obtained, as shown in Figure 8.

Figure 8. List of I/O Variables

E/S

	Nombre	Tipo de datos	Dirección	Rema...	Acces...	Escrib...	Visibl...	Comentario
1	SPHE	Word	%IW96	☐	☑	☑	☑	Sensor de PH en la Entrada
2	SPHS	Word	%IW98	☐	☑	☑	☑	Sensor de PH en la Salida
3	STE	Word	%IW100	☐	☑	☑	☑	Sensor de Turbiedad en la Entrada
4	STS	Word	%IW102	☐	☑	☑	☑	Sensor de Turbiedad en la Salida
5	SNTQ1	Word	%IW104	☐	☑	☑	☑	Sensor de Nivel en el Tanque del Químico 1
6	SNTQ2	Word	%IW106	☐	☑	☑	☑	Sensor de Nivel en el Tanque del Químico 2
7	SNTQ3	Word	%IW108	☐	☑	☑	☑	Sensor de Nivel en el Tanque del Químico 3
8	SNTQ4	Word	%IW110	☐	☑	☑	☑	Sensor de Nivel en el Tanque del Químico 4
9	SNTA1	Word	%IW112	☐	☑	☑	☑	Sensor de Nivel en el Tanque del Almacen...
10	SNTA2	Word	%IW114	☐	☑	☑	☑	Sensor de Nivel en el Tanque del Almacen...
11	SNTA3	Word	%IW116	☐	☑	☑	☑	Sensor de Nivel en el Tanque del Almacen...
12	SCL	Word	%IW118	☐	☑	☑	☑	Sensor de Cloro Libre
13	SCE	Word	%IW120	☐	☑	☑	☑	Sensor de Caudal en la Entrada
14	SCFM1	Word	%IW122	☐	☑	☑	☑	Sensor de Caudal en los Filtros del Módulo
15	SCFM2	Word	%IW124	☐	☑	☑	☑	Sensor de Caudal en los Filtros del Módulo
16	SCS1	Word	%IW126	☐	☑	☑	☑	Sensor de Caudal en la Salida 1
17	SCS2	Word	%IW128	☐	☑	☑	☑	Sensor de Caudal en la Salida 2
18	SCS3	Word	%IW130	☐	☑	☑	☑	Sensor de Caudal en la Salida 3
19	SCS4	Word	%IW132	☐	☑	☑	☑	Sensor de Caudal en la Salida 4
20	SCS5	Word	%IW134	☐	☑	☑	☑	Sensor de Caudal en la Salida 5
21	PI	Bool	%I2.4	☐	☑	☑	☑	Pulsador de Inicio
22	PP	Bool	%I2.5	☐	☑	☑	☑	Pulsador de Parada
23	PPE	Bool	%I2.6	☐	☑	☑	☑	Pulsador de Parada de Emergencia
24	SM0	Bool	%I2.7	☐	☑	☑	☑	Selector Modulo 0
25	SM1	Bool	%I3.0	☐	☑	☑	☑	Selector Modulo 1
26	SM2	Bool	%I3.1	☐	☑	☑	☑	Selector Modulo 2
27	BDQ1	Word	%QW144	☐	☑	☑	☑	Bomba Dosificadora del Químico 1
28	BDQ2	Word	%QW146	☐	☑	☑	☑	Bomba Dosificadora del Químico 2
29	BDQ3	Word	%QW148	☐	☑	☑	☑	Bomba Dosificadora del Químico 3
30	BDQ4	Word	%QW150	☐	☑	☑	☑	Bomba Dosificadora del Químico 4
31	ILV	Bool	%Q152.4	☐	☑	☑	☑	Indicador Luminoso Verde
32	ILA	Bool	%Q152.5	☐	☑	☑	☑	Indicador Luminoso Amarillo
33	ILR	Bool	%Q152.6	☐	☑	☑	☑	Indicador Luminoso Rojo
34	IS	Bool	%Q152.7	☐	☑	☑	☑	Indicador Sonoro
35	ABDQ1	Bool	%Q152.0	☐	☑	☑	☑	Alimentación Bomba Dosificadora del Quí...
36	ABDQ2	Bool	%Q152.1	☐	☑	☑	☑	Alimentación Bomba Dosificadora del Quí...
37	ABDQ3	Bool	%Q152.2	☐	☑	☑	☑	Alimentación Bomba Dosificadora del Quí...
38	ABDQ4	Bool	%Q152.3	☐	☑	☑	☑	Alimentación Bomba Dosificadora del Quí...
39	<Agregar>			☐	☑	☑	☑	

Source: own.

2.6. Programming sequences of operation

In this section, the structures of the operating modes are proposed together with the screens or images that the HMI must have to allow the operator to get information and interact with the system. In the design of the graphcets, the abbreviation or designation of codes is sometimes used to refer to variables or actions.

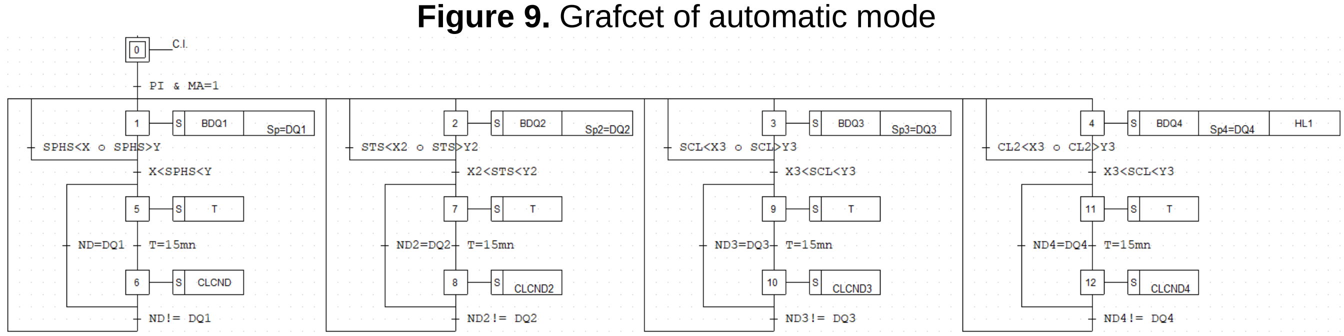
2.6.1. Automatic mode

The normal operation is related to the sequence of operation where the input and output devices of the system work being conditioned by the variables. This mode is developed on the basis of the following graphcet (See Figure 9) and then will be taken to Ladder programming language.

The initial conditions for this mode of operation are:

- Manual mode deactivated ("0")
- Maintenance mode deactivated ("0")
- Module 0 activated ("1")
- Metering pumps off ("0")
- Level of non-zero chemical tanks.
- Initial chemical dosage values within range 0.1 – 30 ppm
- DQ# is equal to the dosage value of the chemicals.

Figure 9. Grafcet of automatic mode



Source: own.

For this mode an HMI image is required to enter the initial values of the dosing, and the main screen of the mode where the concentrations being dosed and the values of the input parameters that feed back into the process can be observed.

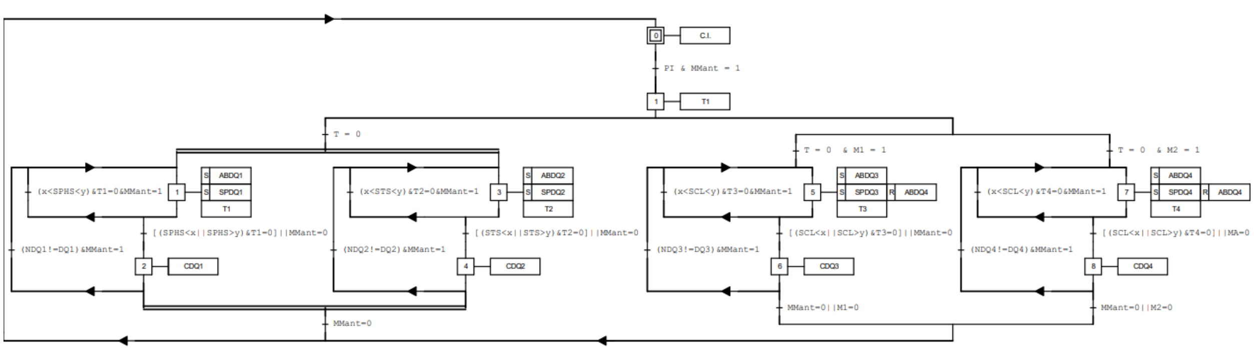
2.6.2. Maintenance mode

The maintenance operation (Figure 10) is the mode that the system adopts to be able to manually wash the tanks, filters, settlers, etc., without creating errors in the measurements and altering the supply of reagents, in this mode it must be selected which of the two treatment modules will be deactivated while maintenance is being performed.

The initial conditions for this mode of operation are:

- Manual mode deactivated ("0")
- Manual mode deactivated ("0")
- Module 0 activated ("1")
- Metering pumps off ("0")
- Level of chemical tanks different from zero
- Initial chemical dosage values within range 0.1 – 30 ppm
- DQ# is equal to the dosage value of the chemicals.

Figure 10. Grafcet of the maintenance mode.

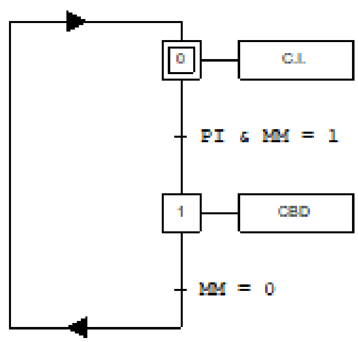


Source: own.

2.6.3. Manual mode

The system operates at the will of the operator giving him the power to set the dosing valves at will or deactivating them and allowing dosing by means of manually operated valves based on the grafcet in Figure 11.

Figure 11. Grafcet of manual mode and alarm



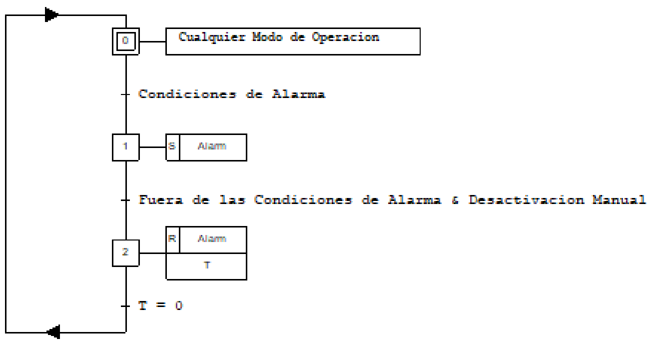
Source: own.

For this mode, only one HMI image is required to activate the mode and control the metering pumps.

2.6.4. Alarms

For the alarm sequence, the following graph is proposed (Figure 12), where its behavior is summarized, the alarms will be activated in any operation mode and through the alarm conditions, for the deactivation it is required to be out of the alarm conditions and a manual deactivation, after that it will give a grace time, where it will be on alert.

Figure 12. Alarm Grafcet



Source: own.

3. Results y Discussion

3.1. Screens

The navigation panel (Figure 13) or main menu where the user has access to different functions with which he can interact, in this panel appears the configuration option, records, readings, manual mode, automatic mode and maintenance, to return to the main menu you must click on the figure of the house that is in a light aquamarine blue square in the upper left corner and to turn off the screen the red off icon in the lower left corner.

Figure 13. Navigation Panel

Source: own.

Figure 14 below shows the configuration panel where the user must enter the initial concentrations of the dosing tanks taken in the laboratory tests, both the jar test and the breakpoint chlorination test, by clicking on the data entry boxes (white) in order to correctly supply the reagents.

Figure 14. Configuration Panel

Source: own.

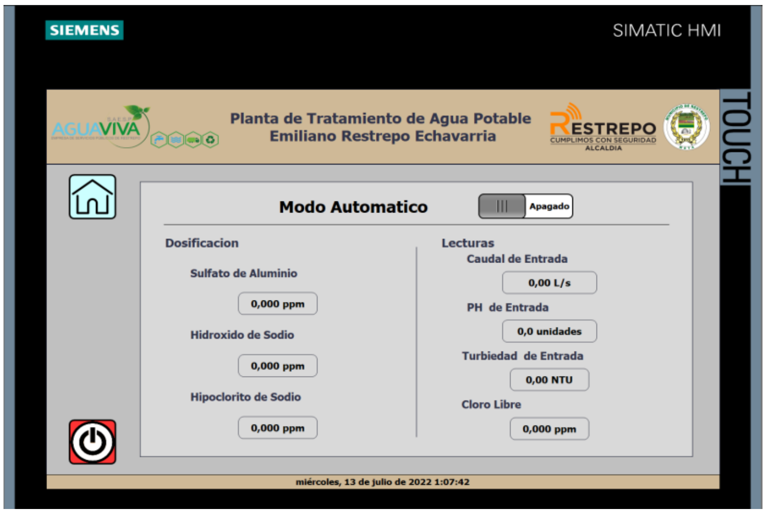
In the following Figure 15 is the Logs panel which is only informative, where the inconveniences that the system has had, unaccepted ranges in the measurements with date and acquired value are displayed.

Figure 15. Logs panel

Source: own.

The automatic panel (Figure 16) has a switch at the top, which activates or deactivates the mode, this panel is informative and when activated it will show the readings of the system input physicochemical variables (raw water) plus the free storage chlorine and the respective automatic dosing of the reagents.

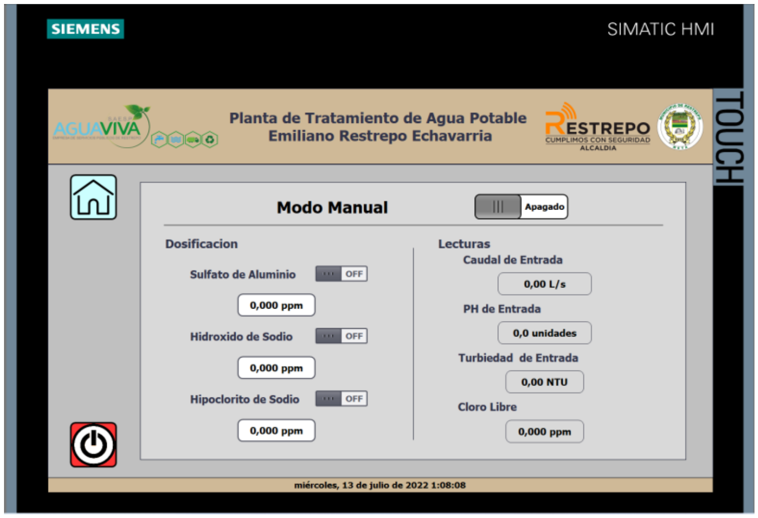
Figure 16. Automatic mode panel



Source: own.

The Manual Mode Panel (Figure 17) has a switch at the top that activates or deactivates the mode. This panel is interactive and when activated, it will show the readings of the physicochemical variables that must be taken into account for the dosing of the reagents, allowing the pumps to be turned on or off at will and the concentrations to be changed from the data entry boxes (white).

Figure 17. Manual mode panel



Source: own.

Through this function, which is integrated in the HMI screen options, we can display warnings (Figure 18) in case any parameter or level is close to a critical value; additionally, records are generated for later analysis.

Figure 18. Warnings

Avisos de bit

ID	Nombre	Texto de aviso	Categoría
1	Aviso PH	PH fuera de rango	Warnings
2	Aviso Turbiedad	Turbiedad fuera de rango	Warnings
3	Aviso Cloro	Cloro fuera de rango	Warnings
4	Aviso Nivel Bajo del Q1	Nivel Bajo del Quimico 1	Warnings
5	Aviso Nivel Bajo del Q2	Nivel Bajo del Quimico 2	Warnings
6	Aviso Nivel Bajo del Q3	Nivel Bajo del Quimico 3	Warnings
7	Aviso Nivel Bajo del Q4	Nivel Bajo del Quimico 4	Warnings
8	Aviso Nivel Tanque 1	Nivel del Tanque 1 de Almacenamiendo Baj	Warnings
9	Aviso Nivel Tanque 2	Nivel del Tanque 2 de Almacenamiendo Baj	Warnings
10	Aviso Nivel Tanque 3	Nivel del Tanque 3 de Almacenamiendo Baj	Warnings
11	Aviso Caudal	Cuidado Caudal Alto	Warnings
12	Aviso Caudal Bajo	Cuidado Caudal Bajo	Warnings

Source: own.

4. Conclusions

Diagnosing the state of the DWTP before developing the automated system is a fundamental phase for the development of the project because the necessary parameters to comply with the regulations governing water purification are decided, in addition to finding the critical points and presenting actions to mitigate or solve them.

The critical points found were the lack of monitoring and registration in the measurement of physicochemical variables and dosage, since it is done by trial and error due to the experience of the operators, causing possible risks such as overloading the water with chemicals, or the inefficiency of responding to the change of the water components due to the weather.

An effective and efficient automated system is designed focused on recording the readings of physicochemical variables and dosing control through electric pumps to ensure the quality of the water provided to the population of Restrepo.

The feasibility of the project is based on compliance with the requirements of the public utilities company and the RAS regulations that place this system as a medium-high level of complexity and its functionality is visualized in an HMI by the feasibility that this offers the operator to report the operating status of the automated system.

Automation is essential for industrial processes due to its reliability, high performance and cost reduction in the supply of inputs, labor and other benefits, the use of technology is essential to have a better quality of life.

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